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**ENDANGERED SPECIES – SOLID ROCKET MOTOR
MANUFACTURERS: PREVENTING A NATIONAL ASSET
EXTINCTION**

by

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ABSTRACT

For the foreseeable future, US policy requires an effective and credible strategic nuclear deterrent capability. Two of the three legs of the current triad providing the deterrent are entirely dependent on Solid Rocket Motors (SRMs) to fulfill that mission. The age of the current SRMs, based on history and Aging Surveillance data, suggest replacement will be necessary to meet current requirements.

Over the last 15 years, economic and policy factors caused the industrial base providing those SRMs to shrink from five down to two remaining producers. Multiple studies by both industry and government concluded overcapacity still exists and, without intervention, the critical skills to produce the next generation SRMs is at high risk of being unavailable when needed.

This study used a problem/solution strategy to assess several options to reduce this risk and retain these crucial capabilities. It concluded the plans being evaluated are necessary but not sufficient to sufficiently reduce the risk. While not evaluated in this study, interdependence exists between NASA and DOD and impacts the outcome. Success in retaining the necessary capability requires additional funding which must be intelligently applied and coordinated between Air Force, NASA, and the Navy.

INTRODUCTION

“The United States provides a nuclear umbrella over roughly thirty allied countries—in NATO, the Western Pacific, and the Antipodes. The U.S. deterrent thereby remains a principal barrier to proliferation for in its absence there is little question that others would seek to create their own nuclear capabilities. Consequently, the credibility of the U.S. deterrent remains essential in maintaining international stability.”¹

Since November 1960, when the USS George Washington began its initial strategic patrol, the bulk of U.S. nuclear deterrent missile forces, both land and sea based, have used Solid Rocket Motors (SRMs) to propel their payloads. Over the last twenty years many changes occurred. These include the war on terrorism and its cost, the recent economic downturn, and continually evolving national policies and priorities. None of these changes has altered the deterrent mission. Many of these changes, however, created a direct and negative impact on the United States’ (US) ability to sustain the critical industrial capability to design, produce, and sustain large SRMs (large being defined as greater than a 40 inch diameter).² This industrial base is responsible for the sustainment and potential replacement of those SRMs comprising America’s land and sea based strategic nuclear deterrent forces. If no action is taken, and the facilities, knowledge, and skills resident in this industrial base are allowed to continue to atrophy, within five to ten years it will reach a condition the Defense Science Board (DSB) concluded was at high risk of being “below critical mass” and may not be able to sustain and/or replace these SRMs.³



Figure 1 USS George Washington Test Launch, 1960⁴

The decision to use SRMs as the booster choice for these missiles was made by both the Navy and Air Force (USAF). Navy research concluded “handling volatile fuels like liquid oxygen during uncertain conditions at sea was much too dangerous.”⁵ For both USAF and Navy, their compact size (see Figure 2), reliability, and maintainability made them the superior choice. These features, particularly the stability for long-term storage/deployment and quick reaction ability, cannot be replaced by other existing options.

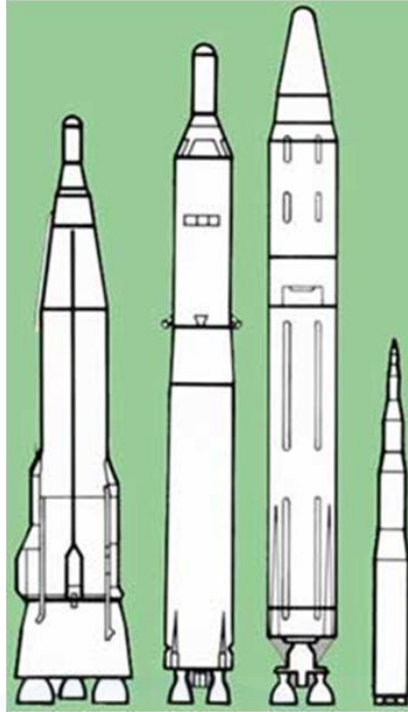


Figure 2 Relative Size - US Intercontinental Ballistic Missiles

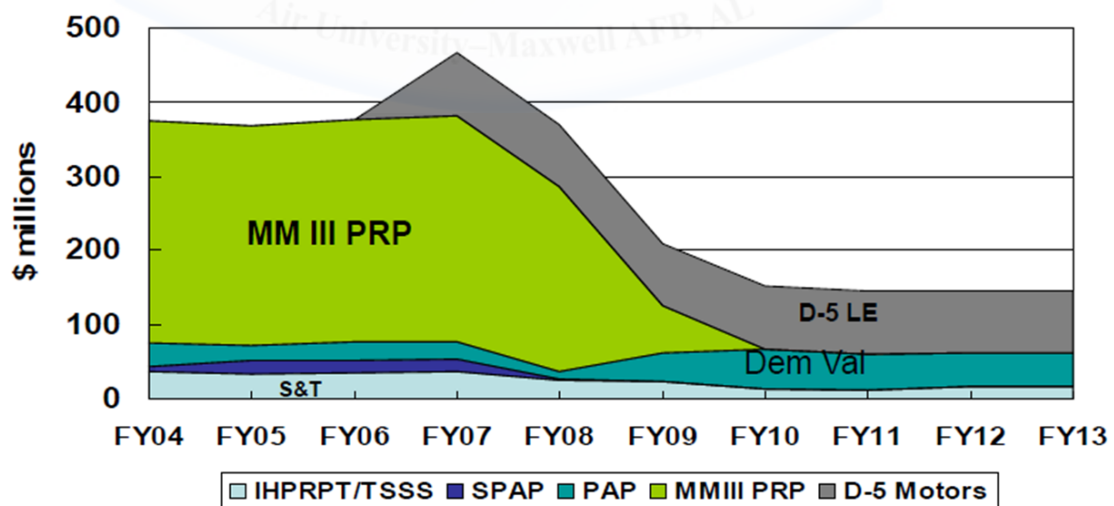
(Left to Right – Atlas, Titan I, Titan II, Minuteman III)⁶

Space launches (approximately 50 percent of US launches projected for 2011), including NASA missions, commercial satellites and military payloads also depend on large SRMs to achieve the necessary performance. Until recently, the combination of these missions sustained the key industry players.

Unfortunately, with the upcoming end of Space Shuttle missions, the cancellation of the Constellation/Ares program, and no other new programs on the horizon, this is no longer the case. The current administration expressed a desire to use commercial vehicles for NASA's access to space. Providers of these vehicles, primarily combinations of Liquid Rocket Motors (LRMs) and SRMs, and foreign competitors might argue free market forces should decide the future of these businesses and commercial/private sector launch providers can fulfill the needs. However, SRMs provide unique capabilities critical to US national security policy – especially the strategic deterrent mission (described in Section 2). The government is the only customer for

these high performance systems. Therefore, the problem does not lend itself to free market forces and direct government intervention is likely required.

DOD currently has programs in place through which resources are being provided to develop new technologies and, to a minimal extent, utilize the production facilities. On the technology side, these include the Integrated High Payoff Rocket Propulsion Technology Program (IHPRPT), The Sustainment of Strategic Systems (TSSS) efforts, and the Propulsion Applications Programs (PAP for USAF), and Strategic Propulsion Applications Program (SPAP for the Navy). In the production arena, the Navy has conducted low-rate production for Trident II D-5 (hereafter referred to as D-5) motors since 1999. The USAF, per Congressional direction, is now developing the requirements and plans for its own warm-line (interchangeably referred to as low-rate production throughout).⁷ Funding levels (or estimates) for the period from 2004 through 2013, including production and technology, are shown in Figure 3.



Large reduction in projected Production and S&T funding ICBM Dem-Val

Source: DoD DDR&E

Figure 3 Strategic SRM Funding⁸

The continuing decline of the SRM industrial base is a problem in critical need of a solution if the US is to maintain two of the three legs of America's strategic deterrent triad. This paper will examine how the Department of Defense (DOD) can use its limited and very likely decreasing, budgets to effectively retain this critical strategic resource. Using the problem/solution methodology, the relevant factors will be identified, the measures for analysis determined, and possible solutions described. These solutions will then be analyzed against the measurement criteria to finally determine the best option and recommend a course of action.

DESCRIPTION OF PROBLEM

Aerojet-General Corporation (Aerojet) and Alliant Techsystems, Inc (ATK) are currently the only two remaining designers and producers of large, high performance SRMs in the US. The reduction, from five companies to two occurred over the last 15 years as illustrated in Figure 4.

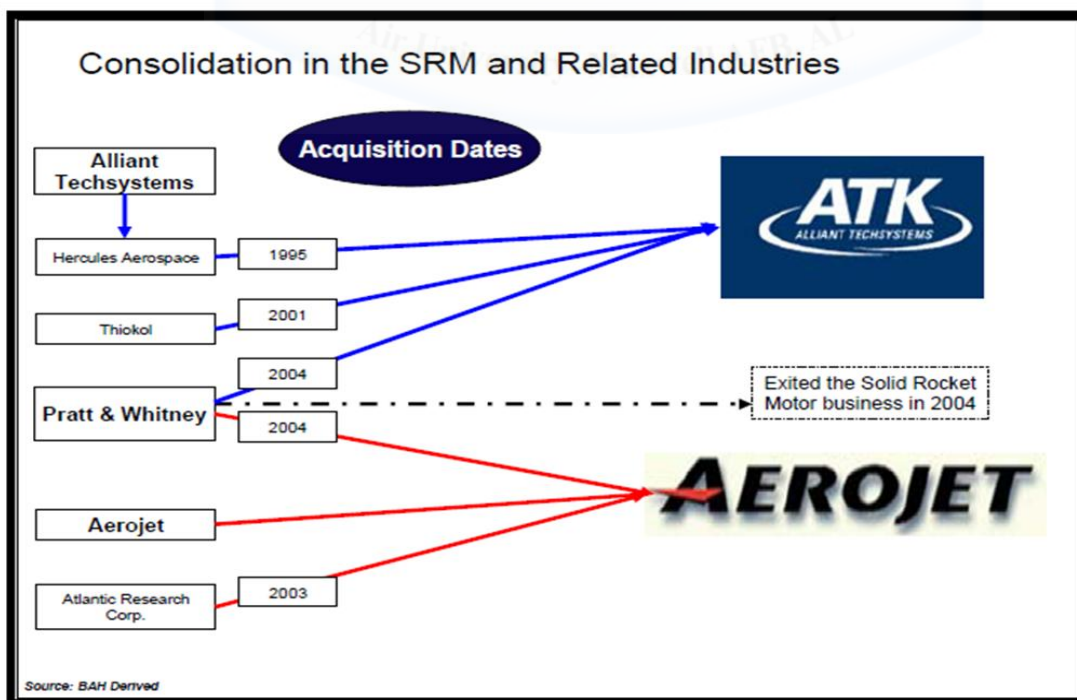


Figure 4 SRM Industry Consolidation⁹

Retaining this capability is critical to US future national security in the following two ways. Without the resources and technical knowledge in these organizations, America may be unable to maintain its current strategic deterrent forces and will likely face major challenges in providing new hardware when required. In addition, the ability to effectively access space will either be restricted, more costly, or dependent on foreign sources. The use of SRMs for both strategic deterrent forces and space launch systems results in the DOD and NASA being mutually dependent, to varying degrees, on the continued stability of these two companies.

Key Issues

The key issues relevant to this discussion fall into three major categories. First, there are strategic issues which create the most critical need to retain the skills and capabilities resident in these companies. The second issue is the business conditions creating the challenges these organizations now face. Finally, the paper will discuss the key facilities, critical skills, and competitive conditions, considered in the recommendations – primarily involving the retention of the facilities and skills required to produce an SRM successfully and safely.

Strategic Issues

The strategic issues are simple to describe. Since the deployment of the first ballistic missile submarines, US nuclear deterrent missile forces have predominantly used SRMs to propel their payloads. The Navy has never used another option for its Sea Launched Ballistic Missiles (SLBM) in any iteration of Polaris, Poseidon, Trident I (C-4) or Trident II (D-5). The USAF did deploy a limited number of operational LRMs (approximately 180 combined Atlas, Titan I, or Titan II), but “By the end of 1967, the Nation had 1,000 Minuteman missiles on alert in six separate deployment areas.”¹⁰ The compact size (described in Figure 2), reliability, maintainability, and ability to remain on alert and be launched very quickly (given they do not

need to be fueled first) are features not available with another existing option. In addition, each of the heavy lift space launch systems (Atlas, Delta, Titan) used in commercial and government launches have configurations relying on SRMs to achieve their missions. Many of these space launches (conducted by NASA or USAF) are critical to national security as well.

The current versions of US strategic deterrent systems (MM III and D-5) have service life requirements unlikely to be achievable with the current SRMs. Congressional direction stated, “The SecAF shall modernize MM III ICBMs...assets required to maintain a sufficient supply of launch test assts and spares to sustain the deployed force of such missiles through 2030.”¹¹ D-5 has a requirement of 2042 to coincide with the hull life of the current Ohio class submarines.¹² Notional MM III planning is to replace the current motors in the 2020’s.¹³ D-5 is expected to need replacements in a similar time frame.

Business Issues

The key issues on the business side all have a direct effect on the viability of the SRM manufacturers and their sub-tier suppliers. These conditions include reduced demand and increased competition. Although the sub-tier suppliers will not be discussed in any detail due to time and resource limitations, it is worth remembering they provide many unique parts and materials. These items are used in the larger strategic SRMs, but can also be crucial to the tactical (air-to-air, ground launched anti-tank, etc.) systems and the decreased demand will, at a minimum, impact their cost. The issues include an increasing dependence on space, the paradoxical decline in demand for launches, increasing competition, and US government policies.

In the last half century, the international community, and particularly the US, has become increasingly dependent on the use of space for both national security needs and commercial

activities. As noted by the US Office of Science and Technology Policy (OSTP), “Critical government space missions include defense and national security needs, science and technology, weather forecasting, and positioning, navigation, and timing services.”¹⁴ In addition, space is crucial for voice and data communications, remote sensing, commercial Global Positioning Systems and a multitude of other uses. These capabilities cannot be maintained without reliable, cost-effective access to space.

The second issue is despite the increasing dependence on space, there is, counter intuitively, a declining demand for launch services. This apparent paradox is actually caused by the space industries and SRM producers being a victim of their own success. Most on orbit systems have been able to significantly exceed their initial service life expectations, reducing the number of launches required to replenish and maintain capabilities. As technology has advanced, the payloads have also gotten smaller, lighter, and more capable, reducing the demand for the heavy lift booster configurations, which is where SRMs have contributed most in the commercial and government space launch arena. The ICBM and SLBM SRMs also consistently exceeded their design life expectancies – often by more than 100% as shown in Table 1.

Table 1 Strategic SRM Design Goal vice Deployment¹⁵

System	Design Life Goal (years)	Length of Deployment (years without refurbishment)
Trident I (C-4)	10	27
MM III (First Stage)	10	32
MM III (Second Stage)	10	17
MM III (Third Stage)	10	17

In addition, many of these SRMs are still used for other purposes and are far beyond their deployment ‘life’. For example, the Minuteman II (MM II) SRMs have been successfully tested

up to an age of over 33 years.¹⁶ This decreases demand for new SRMs in two ways. First, it pushes the need for replacement motors farther into the future. In addition, the older but still serviceable motors are used by various other activities such as the Missile Defense Agency and the Rocket System Launch Programs. They use these motors for target vehicles and other applications (especially Research, Development, Test, and Evaluation missions) eliminating additional production and/or development. This is a good news and bad news scenario. The ability to use the old assets reduces current costs to the long-term detriment of the industry.

Along with the decreasing demand, there is increased competition – mostly in the form of other nations in need of launch services developing their own capability (India, Japan) or purchasing the services from Russia, China, or the French company Arianespace. As shown in Figure 5, the total number of launches decreased and the percentage performed by the US has declined. While not all of these launches involve the use of SRMs (the booster configurations are highly payload dependent), it is representative of the declining demand.

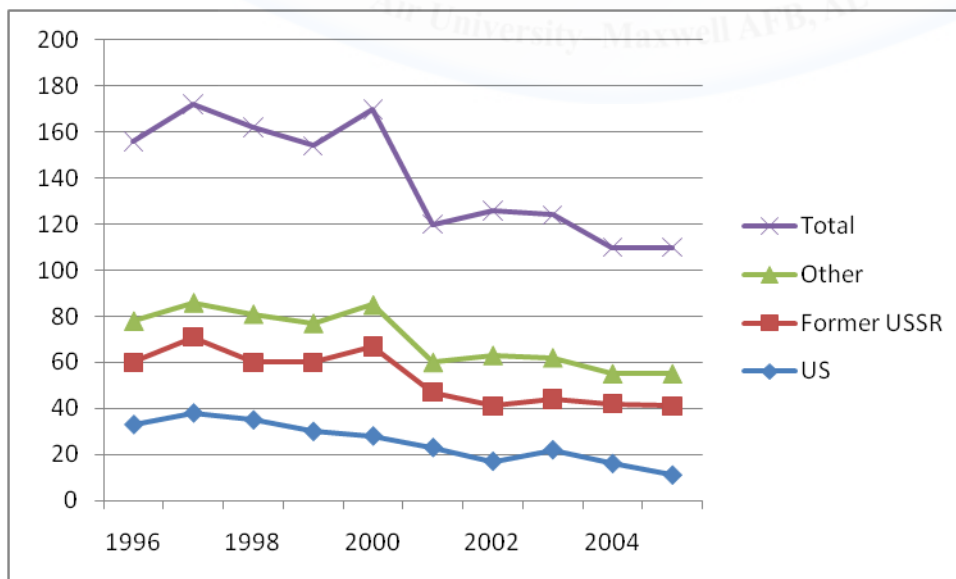


Figure 5 World-wide Space Launches, 1996 - 2005¹⁷

US Government policies also created a negative impact. As reported by the Office of the Under Secretary of Defense for Acquisition, Technology & Logistics (OUSD/AT&L), “The significant drawdown of defense budgets during the 1990s and the collapse of the demand for commercial launch capabilities during the late 1990s and early 2000s resulted in significant SRM industry consolidation, a ‘lean’ industrial base, and underutilized production facilities.”¹⁸ This decline has continued and, although the tactical business segment is expected to grow modestly through FY 2013, the use of large SRMs is anticipated to decrease by 50 percent.¹⁹ Making matters worse is the cancellation of NASA’s Constellation program which, according to Brett Lambert, DOD’s industrial policy director, “...changes everything. That is a game changer.”²⁰ Mr. Lambert’s comment is pertinent because the sheer size of those boosters and the quantities of materials used for their manufacture create a major effect on the SRM supplier base. Table 2 illustrates this size factor. The use of SRMs is not quite as critical to NASA (once the shuttle retires) or the commercial launch industry as they can (with time and money) potentially substitute Liquid Rocket Motors (LRMs) for their missions.

Table 2 SRM Propellant Quantity Comparison²¹

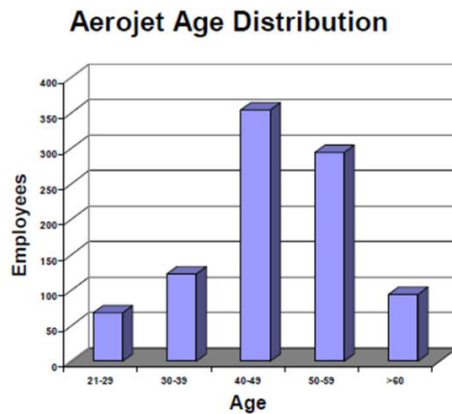
COMPARING SPACE SHUTTLE RSRM TO OTHER SRMS		
Missile Program	Pounds of Propellant	Equivalent # of SRMS to Equal One Space Shuttle RSRM
Space Shuttle RSRM	1,106,059	1
Trident II D-5	110,200	10
Minuteman III (MM III)	66,642	17
Ground Missile Defense (GMD)	43,469	25
Kinetic Energy Interceptor (KEI)	20,026	55
Patriot Advanced Capability-3 (PAC-3)	350	3,160
Guided Multiple Launch Rocket System (GMLRS)	216	5,121
Advanced Medium-Range Air-to-Air Missile (AMRAAM)	113	9,788
Hellfire	20	55,303
Javelin	3	368,686

An additional policy (and budgetary) consideration is the conflict created by the desire to reduce cost through competition. This benefit must be weighed against two factors. First, competition requires at least two sources, increasing the cost to retain healthy suppliers, when both are currently underutilizing available facilities. Any analysis must also consider the benefit two sources provide when a single-point failure creates potentially catastrophic strategic and policy implications.

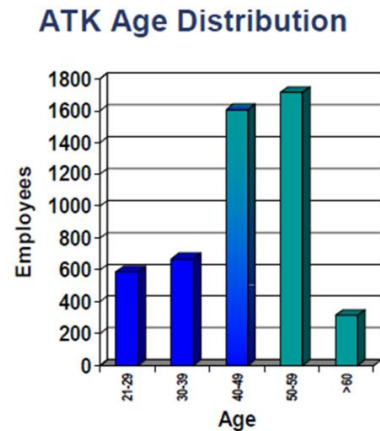
Facilities, Skills and Capabilities

The unique capabilities of high performance SRMs, particularly the ability to provide a large amount of energy from a physically compact package, present some inherent disadvantages. While they are very safe and relatively insensitive once manufactured, the highly energetic materials required in manufacturing cause the process to be very sensitive and potentially hazardous – in fact explosive. Experience in the early development history provided many lessons. One that is crucial to the discussion is the relationship between the quantity of explosives stored or used in a given area and the safe operation of the plants. These “quantity-distance relationships” result in safer manufacturing plants but require large footprints. Clearly, land is an increasingly valuable resource and this would be a significant issue if these facilities were lost to the industry.

When it comes to the skills, capabilities and knowledge necessary to design, build and maintain SRMs, there are two key factors at the heart of the concern. First is an aging workforce. Figure 6 illustrates age distributions for the workforce at the primary locations for strategic SRM operations of both Aerojet and ATK.



20% of workforce is < 40 years old



26% of workforce is < 40 years old

Note: Aerojet Data reflects Sacramento Facility & ATK data reflects Space Systems Division

Source: Aerojet & ATK

Figure 6 Age Distribution - Strategic SRM Workforce²²

The second challenge is loss of the current experience base. With no new development efforts in the foreseeable future, the older workforce is likely to retire (or be laid off). New talent will be extremely difficult to attract without an interesting or exciting future project and without the older workforce, there will be no one to train and mentor new personnel.

Of the many skills, capabilities, and knowledge lost if Aerojet and ATK are allowed to atrophy further, the ‘art’ involved in safely making SRM propellants is one of the most crucial. As mentioned above, once the manufacture and ‘curing’ of these materials is complete, they are relatively insensitive and safe – it takes a very specific (and not easy to achieve accidentally) set of conditions to start and sustain the burning of the propellant. During the manufacturing process, however, the situation is quite different. A crucial aspect is in the design of equipment which mixes the propellant. The materials are highly viscous and at this stage, sensitive to ignition from a small spark. The need to ensure complete mixing, which allows them to burn in a consistent, predictable way, must be delicately balanced with the need to have adequate

clearances between the mixing bowls and blades. Both Aerojet and ATK, with more than 40 years of past experience, have design specifications which would allow replacement equipment to be built in the future. However, should the tribal knowledge describing *why* things are done as they are be lost, they or another organization attempt to enter the business in the future, someone will decide they can do it less expensively and lives and facilities will almost certainly be the cost.

There are similar types of issues on the design side of the equation. Here, the technology in use to do design work today presents of a two-edged sword. There are computer based design and analysis tools in use allowing a competent engineer, familiar with the software, to do basic design of most components of a rocket motor. However, as with propellant manufacture, the *why* of the models will be lost. A lack of experience, leading to fundamental understanding how the SRMs work, will make it difficult (at best) to advance the state of technology for the future. Perhaps worse for aging systems like MM III or D-5, no one having the ability to resolve a problem when aging issues arise will remain.

MEASUREMENT CRITERIA

The key factors differentiating among the options are their ability to: ensure the appropriate facilities remain available; guarantee the availability of knowledgeable personnel with the necessary design and manufacturing skills and capabilities; and, positively influence competition in the near and long terms. These three areas will be further defined and the criteria identified in the paragraphs to follow.

Facilities

The impact of the alternatives on facilities will be assessed against their ability to utilize the processes with sufficient frequency to ensure safe and reliable operations and produce a

predictable, quality product. Currently, the facilities produce SRMs for commercial launch, Missile Defense Agency (MDA) programs, and the low-rate production for D-5 motors. All of these motors are similar enough in most design features, manufacturing processes, and materials to provide the requisite experience, but only the effect of D-5 or MM III activities will be assessed.

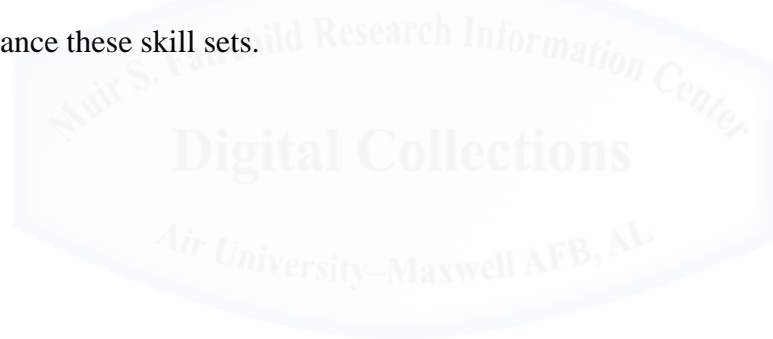
An additional facilities consideration is the ability (including, in this case, personnel) to provide the company's shareholders adequate return on their investments. Decisions by Aerojet and ATK relative to facilities (and personnel) retention and capacity are driven by financial conditions as well as the operational considerations described. This paper cannot, due to both available resources and the proprietary nature of the decision calculus, assess the alternative effects in detail against the financial aspect. It will, therefore, simply identify whether the usage rate would increase, decrease, or remain the same for a given alternative.

Critical Skills

The critical skills required to assure America's ability to maintain the existing SRM fleet and to design, develop, and produce the next generation were well characterized in a 2006 study by the Defense Science Board (DSB) and generally need not be re-invented for this paper. The skills and associated definitions as defined by the DSB are shown in Figure 7 with more detailed descriptions the sections to follow. Across all of these critical skills areas, but not specifically included in the DSB study, the capability to address unexplained results or failures must be addressed. As the DSB noted, relative to MM III, "No one who designed the original MM III components in the late 1960s is actively engaged in the program, so root causes of design failure, should one occur, could be difficult to determine and correct."²³ Few, if any, of the original system designers are available. In addition, significant failures of SRMs have been rare since

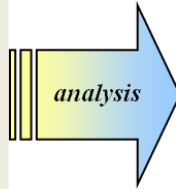
1980 – I-Shih Chang reports 98.8% of commercial SRMs between 1980 and 1999 were successful.²⁴ This success rate is again good news and bad news. There is a significant amount of art in the performance of failure analysis and determination of the root cause. The lack of failures means experience in this skill is virtually non-existent. With both MM III and D-5 SRMs continually aging it could suddenly become more critical.

Another experience set, necessary to both the Sustainment and Development critical skill arenas, and unique to strategic systems, stems from the requirements to operate in the environment created by a nuclear exchange. This demands personnel have expertise in radiation hardening and the ability to understand, assess, and account for the nuclear environment effects created during a nuclear exchange. Therefore, the alternatives will also be assessed against their capability to enhance these skill sets.



"Critical Skills" include:

- Development Capabilities and Skills
- Production Capabilities and Skills
- Sustainment Capabilities and Skills
- Materials Availability
- Critical Suppliers
- Special Facilities (Test, etc)



Assessment Definitions

Green

- Critical mass retained
- Can be readily reconstituted
- 75 % covered
- > 2 area experts

Yellow

- Critical mass marginal
- >45% to <75% covered
- 1 expert + 1 mentoree

Red

- Below critical mass
- < 45 % covered
- Reconstitution risk
- No expert or no mentoree

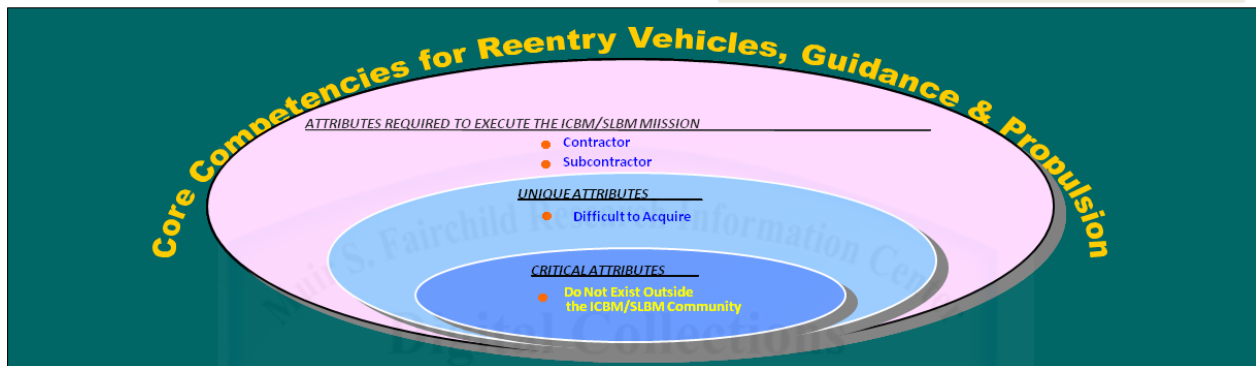


Figure 7 Critical Skills and Definitions²⁵

The DSB study concluded the current state of the basic skill sets within the industry is as shown in Figure 8. This was considered the baseline for the assessments in this paper. The alternatives will be rated as improving, maintaining, or degrading the facility, skill, or future competitive environment.

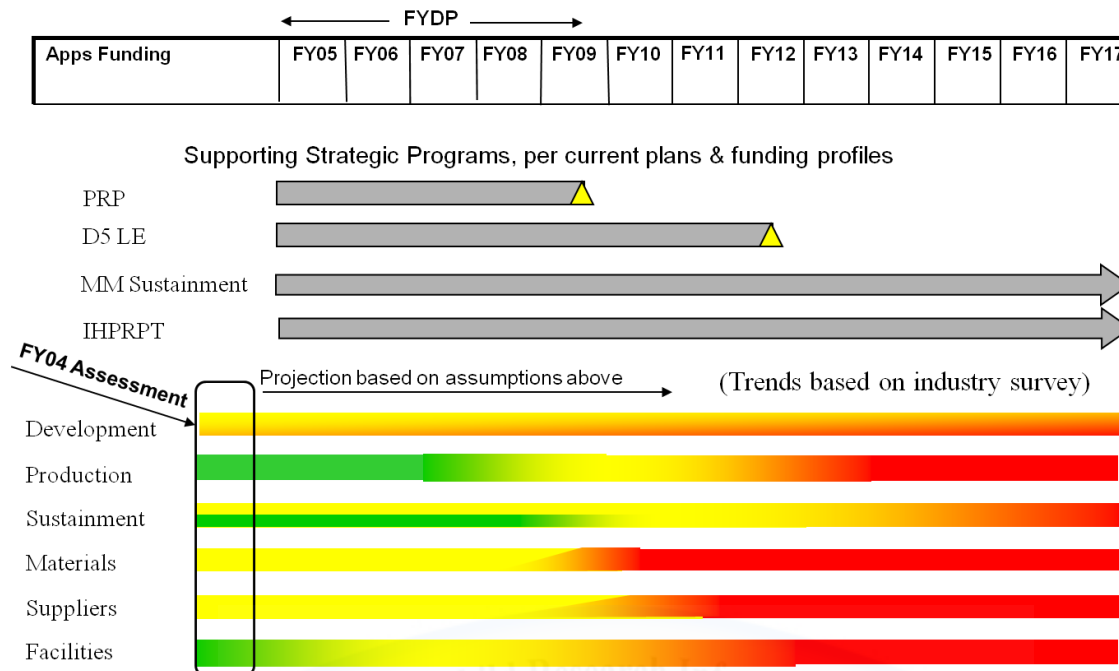


Figure 8 DSB Assessment of SRM Critical Skills²⁶

Development Capabilities and Skills

This area includes the ability to perform systems engineering and integration, component design functions, structural, ballistic, and controls analysis, and design, execution, and evaluation of testing programs, processes and procedures.

Production Capabilities and Skills

Ensuring reliable and safe operations requires equipment and processes are well maintained, and kept up to date. It also necessitates personnel must sufficiently understand equipment designs and the sensitivity of the processes. This ensures effective operations and the ability to anticipate, diagnose, and resolve issues as they occur. In this area, personnel must have a detailed understanding of process control methodologies since the ability to identify trends is more challenging with fewer data points.

Sustainment Capabilities and Skills

This area includes primarily systems engineering and integration activities, refurbishment programs (such as the MM III Propulsion Replacement Program (PRP)), component replacements for individually defective parts or systemic/aging issues, and assessment of testing and Aging Surveillance data. Sustainment activities primarily occur on strategic SRMs since commercial systems are, for the most part, built on a “just-in-time” basis and rarely stored for extended periods.

Material Availability and Critical Suppliers

This capability will not be further addressed in the evaluation since the relative volume of materials used by NASA and the largest commercial SRMs far outweighs the potential for strategic programs to impact the supplier base (see Table 2). Examples of the materials include components of the propellant formulations such as the Ammonium Perchlorate oxidizer and the Hydroxyl-terminated polybutadiene binder.²⁷ This is an area where DOD and NASA must communicate and cooperate and decision makers must account for NASAs impact on DOD.

Special Facilities

These will not be addressed separately in the individual options but will be addressed, when necessary, as part of the facilities discussion. In most cases, the government owns facilities to perform any testing not directly involved in or required by the manufacturing process.

Impact on Competition

This criterion will assess the distribution of funding from the various sources and projects focused on the strategic SRMs. It will assess the impact of this distribution on Aerojet or ATKs ability to compete for future ICBM or SLBM replacement (including design, development,

production, and sustainment) programs. As with the facilities and capabilities, the improvement, maintenance, or degradation of the competitive environment will be reported for each alternative. Although there would be a significant impact on this factor, it is not within the scope of this effort to account for the affect of other SRM business in the commercial and tactical realm.

ALTERNATIVE DESCRIPTIONS

This paper examines four different alternatives including: the “Do Nothing” model, the “Navy” Model (D-5), the “Air Force” Model (MM III), and a “Hybrid” model. There are other options physically possible for the strategic mission including LRMs, hybrid rocket motors (solid fuel and liquid oxidizer), other existing commercial SRMs, or foreign system options. These ‘other’ options will be briefly addressed for completeness, but for reasons to be identified in the Evaluation section, they need not be assessed in detail.

The basic Navy and USAF models are essentially the current philosophies and resulting modes of operation for the two Services and their strategic systems as described in the introduction. The evaluation should be as ‘apples-to-apples’ as possible. Since the DSB (as noted in the Criteria section) has already evaluated the ‘snapshot’ of the current condition, this evaluation will assume some additional funding is provided to fill the gaps in each Service’s current program. Therefore, the assumed additional funding will be applied by the Navy to its SPAP demonstration/validation efforts (currently unfunded) while the USAF applies funds to the low-rate production for which plans (and funding) are being developed. Further, the evaluation will assume the USAF’s warm-line will provide the ‘new’ SRMs via the same process as applied in the recently completed PRP – old propellant and insulation will be removed from existing

motor cases and replaced. In each model, sustainment activities and R&D efforts will continue unchanged.

Do Nothing Model

Also described as the “Gap and Restart” option, this is representative of today’s status quo operations and funding levels, with the impacts on capabilities being as described by the DSB and shown in Figure 8. The result of this assessment is a gap in capability between now and when replacement motors are needed. This requires the Navy to ‘restart’ its design and development skills while the USAF would have the same issue on production operations.

Navy Model

Strategic Systems Programs (SSP) has managed the D-5 industrial base primarily through use of ongoing low-rate production combined with Life Extension (LE) and Aging Surveillance programs to assure the reliability of the fleet SRMs. New production units are typically not notably different in configuration from previously deployed SRMs. This process exercises the Production and Sustainment skill sets along with the existing facilities. Sustainment skills also continue to be utilized through ongoing sustainment funding. The Development skills are, to a small extent, also exercised in the LE efforts when replacements are needed for obsolete components or materials. They would also be used in SPAP, IHPRPT, or TSSS but these efforts have not been a priority for funding.

Air Force Model

The USAF also uses LE and Aging Surveillance programs to aid in maintaining industrial base capabilities and also has relatively stable sustainment funding, but, has no ongoing production efforts. A new low-rate production program is currently in the planning stages. One of the undecided features of this warm-line is whether or not these units are deployable. For this

evaluation (as noted earlier) the assumption will be execution of a PRP-like effort, producing deployable SRMs. The USAF has provided more funding for PAP, IHPRPT, and TSSS efforts but these have never risen to the recommended levels.

Hybrid Model

On significant issue for both the USAF and Navy has been the lack of direction for next generation systems. The result has been PAP, IHPRPT, and TSSS efforts not completely coordinated nor focused on a particular outcome. The key difference in the Hybrid model will be in how the low-rate production funding is applied. The Hybrid will operate in the same mode as the USAF and Navy models for R&D activities and sustainment efforts. In this model, however, the warm-line funding will be coordinated with the demonstration/validation programs (SPAP and PAP) and used in a manner more closely resembling an Engineering and Manufacturing Development (EMD) phase effort as described in the DOD Systems Engineering process.²⁸ The development projects would be further focused on maturing technologies applicable to a next generation system. Motors produced would incorporate technology updates from the development programs and be supplied to other agencies (RSLP, MDA) for use as test or target vehicles. In addition, a program should be created to take either some old assets currently being used by RSLP and MDA or other excess SRMs and intentionally test them to failure.

One additional option should eventually be considered and could apply against any of the previous alternatives if those levels of funding are still insufficient. The government (to include DOD and NASA) should evaluate a government purchase of facilities from ATK and Aerojet sufficient to assure any projected future needs can be met. These facilities would then be run as

Government Owned, Company Operated (GOCO) operations, similar to armories and depots of the past.

COMPARISON OF ALTERNATIVES

OUSD/AT&L has concluded “The SRM industrial base – both prime and subtier suppliers – is capable of meeting most technological and production requirements”, but the “lack of meaningful production orders and limited development efforts for the next decade is not conducive to the long term well being of the industry.”²⁹ The comparison of alternatives focuses the assessment on longer term impacts using a stop-light chart format to display the results. As described in the Measurements Criteria section, an “improving” condition will be considered green and defined as a condition where efforts contributing to skill development will increase and are contained in the planned budget. A “maintaining” condition will be yellow and defined by continuing stable activity, and “degradation” will be red and exist where programs are decreasing or not contained in the budget.

Other Options

The ‘other’ category includes the use of liquid-fueled rocket motors (LRMs), hybrid rocket motors (such as SpaceShipOne designed by Scaled Composites for the X Prize competition), commercial systems, or SRMs from foreign manufacturers.³⁰ For any number of reasons, it would be unwise to become dependent on the use of foreign systems for a US strategic application. Therefore, it will not be considered here.

Current commercial SRM systems and hybrids are not a beneficial alternative. They are designed to neither the high performance levels required for MM III and D-5, nor to operate in

the environments possible during a nuclear exchange. Efforts to upgrade their capability involve the same development time and cost as creating and qualifying new versions of MM III or D-5.

LRMs are likewise not a practical option as they are also not currently designed to operate in nuclear environments. They could have operational timing or safety issues as well, since they can either be fueled only shortly prior to use or would use hazardous ‘storable’ propellants. While LRMs are capable of the requisite performance, the vehicles are, of necessity, much larger (see Figure 2). Their use would require entirely new, much larger and more costly infrastructure for basing and would be completely impractical on a submarine.

Do Nothing Model

The OUSD (AT&L)/IP study published in 2009 concluded “Restarting production operations for SRMs takes a significant amount of time and money”.³¹ The study estimated it would take 3-5 years from a “warm base” and from a cold base, “6-8 years, if feasible at all.”³² The Navy estimated the restart option, producing the current design, would cost twice their current baseline budget plan (2011 – 2025) and for a new design, it would be triple assuming there is “something to restart.”³³ Impacts to the specific criteria are described in the next sections.

Facilities

The facilities will be utilized at the same frequency under this option as they are currently. This could pose a concern for Aerojet as low-rate production and sustainment are currently performed exclusively at ATK. Still, with no overall change, the rating is YELLOW.

Critical Skills

The capabilities are assessed against current programs and funding levels for this model.

Development Capabilities and Skills

For each option, this category will be further broken down to individually address subcategories of: Systems Engineering and Integration; Component Design and Development; Analysis (including structural, ballistic, etc.); Nuclear Environmental Issues; and Failure Analysis and Root Cause Identification.

Systems Engineering and Integration. All current PAP activity is directed to producing demonstration boosters for CSM. The integration responsibilities are not performed by ATK or Aerojet. The rating is RED.

Component Design and Development. CSM is based on current state-of-the-art and no new component design or development is included. The rating is RED.

Analysis. All applicable analysis types are being utilized in the refinement and production of the CSM boosters. The rating is YELLOW.

Nuclear Environmental Issues. CSM does not have applicable requirements to operate in the nuclear environment. The skills are not being utilized and the rating is RED.

Failure Analysis and Root Cause Identification. This skill set would only be exercised in the event of a failure. The rating is RED.

This overall assessment for the Development category is assessed as RED as shown in Table 3.

Table 3 Do Nothing Model - Development Capabilities Assessment

Systems Engineering & Integration	Component Design and Development	Analysis	Nuclear Environmental Issues	Failure Analysis & Root Cause Identification
RED	RED	YELLOW	RED	RED

Production Capabilities and Skills

Since the original production for MM III in the 1970s, both USAF ICBMs and Navy SLBMs have been produced (or refurbished) by ATK. Therefore, the assessment evaluated the affect on ATK. The Aerojet capabilities are considered to be degraded and RED in all categories.

Equipment and Process Design/Maintenance. The facilities used to produce the D-5 SRMs were designed and built prior to or during the 1980s. The Navy warm-line activity and the associated maintenance of the equipment are sufficient to retain understanding of the current equipment design and the associated process. Since there is no program in place to improve the processes or equipment, and the USAF low-rate production is not yet a budgeted item, this capability is rated YELLOW.

Process Control and Assessment. Production programs have continuously placed a high value on process control and consistency. The ongoing warm-line production is judged sufficient to maintain this capability area and its rating is YELLOW.

Failure Analysis and Root Cause Determination. Any major failure analysis would only be conducted in the event of an incident in the actual production process. As failures would not be intentionally induced, this skill would not be utilized on a routine basis. However, as the process control systems detect change, root cause analysis methods are utilized to determine the appropriate disposition of the issue. This capability is assessed as YELLOW.

The resulting overall rating for the Production Capabilities and Skills area is summarized in Table 4.

Table 4 Do Nothing Model - Production Capabilities Assessment

	Equipment/Process Design & Maintenance	Process Control & Assessment	Failure Analysis & Root Cause Determination
ATK	YELLOW	YELLOW	YELLOW
Aerojet	RED	RED	RED

Sustainment Capabilities and Skills

As noted with production, all ongoing activity for MM III and D-5 resides with ATK.

Therefore the same scenario exists and the analysis applies to ATK with Aerojet rated RED.

Systems Engineering and Integration. As issues with defective or aging SRM components are identified, systems engineering and integration processes are applied to determine the correct fix/repair solution and to ensure there is no impact to other aspects of system performance.

There are, however, no specific programs/projects intended to enhance these skills resulting in this capability to be evaluated as YELLOW.

Aging and Surveillance (program design and data evaluation). The low-rate production concept has the advantage of making accurate aging assessment of components less critical for the Navy since the oldest SRM assets are first to be replaced. While the Navy does continue its Aging Surveillance program, the skills required to create and execute an effective program receive less emphasis. The USAF philosophy is highly dependent on early identification of age limiting trends. This effort continues in its current form. With no additional effort on the horizon, the rating for this skill remained YELLOW.

Failure Analysis and Root Cause Determination. The assessment of this capability is virtually identical to the assessment in the Production Process Control area with the evaluations conducted against SRM components vice production processes. The skill rating is also YELLOW for the same reasons.

Nuclear Environmental Issues. These parameters must be accounted for in the initial design process. Therefore, the only utilization of this knowledge would be only if and when a component required replacement fleet-wide and a build-to-print option is not available. As “life-of-type” purchases have been the rule when materials or components may fall into this category, there are minimal opportunities to exercise this skill set. The resulting rating is RED.

The overall evaluation for the Sustainment category is shown in Table 5.

Table 5 Do Nothing Model - Sustainment Capabilities Assessment

	Systems Engineering & Integration	Aging & Surveillance	Failure Analysis & Root Cause Determination	Nuclear Environmental Issues
ATK	YELLOW	YELLOW	YELLOW	RED
Aerojet	RED	RED	RED	RED

Impact on Competition

As mentioned in conjunction with the Production and Sustainment assessments, all of these activities are contracted to ATK. In the absence of development efforts leading to the next generation system, this will degrade the competitive prospects for Aerojet and was therefore evaluated RED.

Navy and USAF Model

The assumptions described in the Alternative Descriptions – the USAF conducting a low-rate production and the Navy reinvigorating its SPAP – preclude either option from an arbitrary, unfair advantage in the assessment. The effect is the models became virtually identical. Therefore they were evaluated only once for brevity.

Facilities

The facilities will be utilized at a greater rate than under the “Do Nothing” option but are still significantly underutilized. The same concern exists for Aerojet as low-rate production for

both MM III and D-5 are still performed exclusively at ATK, but could be marginally reduced with the Navy using SPAP funding. Still, minimal overall change retains the YELLOW rating.

Critical Skills

The addition of a warm production line for MM III and SPAP demonstration/validation effort for D-5 drive changes in this assessment compared to the Do Nothing option.

Development Capabilities and Skills

These skills continue to be utilized to some extent under this model and with the addition of SPAP activities are improved compared to “Do Nothing.” The capabilities in this area will be assessed in the five sub-categories mentioned in the Criteria section.

Systems Engineering and Integration. These skills would be exercised in the PAP and SPAP Demonstration/validation programs. However, the current and near-term future plans for PAP create individual stages for a Conventional Strike Missile (CSM) flight demonstration. The system level engineering and integration efforts are not a responsibility of Aerojet or ATK on this project. A marginal improvement (or delay of degradation) is possible depending on the tasks executed under SPAP, but the rating remains YELLOW.

Component Design and Development. These skills would be utilized in both the IPHRPT and Demonstration/validation programs. With the addition of SPAP the funding levels could approach those recommended by the DSB but the CSM demonstration being conducted on PAP is simply incorporating current state-of-the-art technology. Therefore, the resulting assessment remains YELLOW.

Analysis (Structural, Ballistic, etc). These skills are also maintained through the IPHRPT and Demonstration/validation programs. In addition, they benefit to an extent from ongoing test programs such as the USAF Force Development Evaluation (FDE) and Navy Operational Test

(OT) flight testing and Aging Surveillance static fire testing. These would not be expected to increase under this model. The evaluation of this area results in a YELLOW rating.

Nuclear Environmental Issues. These would be addressed by a Demonstration/validation program if it were developing a strategic SRM. The CSM vehicle is not subject to these requirements and the capability assessment is therefore RED.

Failure Analysis and Root Cause Determination. Any major failure analysis would only be conducted in the event of an incident involving a test failure. As these would not be intentionally induced, this skill would not be utilized on a routine basis. However, a development project does have some additional likelihood of a failure occurring but this is not considered a high enough probability to raise the rating and the evaluation remains YELLOW.

Overall rating for the Development area for the USAF Model is YELLOW and is summarized in Table 6.

Table 6 USAF/USN Development Capabilities Assessment

Systems Engineering & Integration	Component Design and Development	Analysis	Nuclear Environmental Issues	Failure Analysis & Root Cause Identification
YELLOW	YELLOW	YELLOW	RED	YELLOW

Production Capabilities and Skills

As discussed, this section assumes an ongoing, consistently funded, warm-line producing one set (first, second, and third stages) of motors per month to gradually replace the deployed D-5 and MM III SRMs. The impacts on the specific Production skills are described below.

Equipment and Process Design/Maintenance. The facilities used to produce the Trident SRMs were designed and built in the 1980s. The warm-line activity and the associated maintenance of the equipment are sufficient to retain sufficient understanding of the current equipment design

and the associated process. Since there is no program in place to improve the processes or equipment, therefore this capability is rated YELLOW.

Process Control and Assessment. The Trident production programs have continuously placed a high value on process control and consistency. The ongoing warm-line production is judged sufficient to maintain this capability area and its rating is YELLOW.

Failure Analysis and Root Cause Determination. Any major failure analysis would only be conducted in the event of an incident in the actual production process. As failures would not be intentionally induced, this skill would not be utilized on a routine basis. However, as the process control systems detect change, root cause analysis methods are utilized to determine the appropriate disposition of the issue. This capability is assessed as YELLOW.

The resulting overall rating for the Production Capabilities and Skills area is shown in Table 7. The rating is YELLOW.

Table 7 USAF/USN Model - Production Capabilities Assessment

	Equipment/Process Design & Maintenance	Process Control & Assessment	Failure Analysis & Root Cause Determination
ATK	YELLOW	YELLOW	YELLOW
Aerojet	RED	RED	RED

Sustainment Capabilities and Skills

Ongoing sustainment of the MM III and D-5 systems are equivalent to the description provided in the “Do Nothing” option and are not repeated here. The rating is RED.

Table 8 USAF/USN Model - Sustainment Capabilities Assessment

	Systems Engineering & Integration	Aging & Surveillance	Failure Analysis & Root Cause Determination	Nuclear Environmental Issues
ATK	YELLOW	YELLOW	YELLOW	RED
Aerojet	RED	RED	RED	RED

Impact on Competition

As before, all Production and Sustainment operations occur at ATK. With this model, there is some additional development which could, if properly focused on future requirements, improve the Aerojet position, but only marginally. The rating, therefore, remains YELLOW.

Hybrid Model

As described in the Alternatives section, the primary difference between the Hybrid model and the USAF/Navy model is the use of more funds in an EMD-like effort, closely coordinated with the technology development projects. In addition, the option to include testing SRMs intentionally to failure is a significant addition.

Facilities

In an EMD-like environment proposed for the Hybrid option, use of facilities for testing and other specialized activities would experience greater utilization. However, the use of production capabilities facilities will not increase significantly. As production is the important driver for facilities capabilities, the assessment remains YELLOW.

Critical Skills

Under the Hybrid Model, available funding is applied to optimize the benefit to the industrial base as a coordinated whole. Therefore, it could be directed (rather than competed) to Aerojet or ATK as the circumstances require.

Development Capabilities and Skills

With the increased emphasis on EMD-like activities, this Critical Skill set should see improvement in several of the subcategories. Better definition of preliminary requirements for future systems ensures increased focus on appropriate tasks.

Systems Engineering and Integration. These skills would be exercised in the Demonstration/validation programs. However, the current and near-term future Demonstration/validation plans are creating individual stages for a Conventional Strike Missile (CSM) flight demonstration. The system level engineering and integration efforts are not a responsibility of Aerojet or ATK on this project. There could be a marginal improvement (or delay of degradation) depending on the tasks executed under SPAP but the rating remains YELLOW.

Component Design and Development. With the redistribution of priorities and funding from low-rate production and the definition of next generation requirements to focus R&D and Demonstration/validation this skill would see definite improvement. Therefore, the resulting assessment becomes GREEN.

Analysis (Structural, Ballistic, etc). These skills benefit from ongoing test programs such as the USAF Force Development Evaluation (FDE) and Navy Operational Test (OT) flight testing and Aging Surveillance static fire testing. They would be further enhanced in the process of defining the new systems and components. The evaluation of this area results in a GREEN rating.

Nuclear Environmental Issues. These would be addressed by a Demonstration/validation program developing a new strategic SRM. While there would be an improvement, it is unlikely funding would be sufficient for the level of testing necessary to fully exercise this skill. The capability assessment improves to YELLOW.

Failure Analysis and Root Cause Determination. Implementation of the plan to conduct tests to failure and completion of the resulting investigation exercise is potentially the most beneficial aspect of this option. This skill improves to GREEN.

The summary for Development skills is shown in Table 9.

Table 9 Hybrid Model - Development Capabilities Assessment

Systems Engineering & Integration	Component Design and Development	Analysis	Nuclear Environmental Issues	Failure Analysis & Root Cause Identification
YELLOW	GREEN	GREEN	YELLOW	GREEN

Production Capabilities and Skills

The Hybrid option reduces but does not entirely eliminate low-rate production. Some of the production unit reductions would be replaced by building development motors and be provided by Aerojet. These changes are assessed against the same subcategories as in previous options.

Equipment and Process Design/Maintenance. Under the EMD-like concept, some development of process improvements would be expected. However, the facilities and processes used to produce the D-5 and MM III SRMs could not be altered or requalification becomes necessary. Therefore, the process and equipment improvement efforts would be confined to subscale or limited pilot plant scale. While this results in some improvement, it is not sufficient to upgrade the overall rating for this skill. The capability rating remains YELLOW.

Process Control and Assessment. Process control efforts would be applied in production programs. However, the EMD efforts develop the controls for the future system. Therefore this capability area and its rating improve to GREEN.

Failure Analysis and Root Cause Determination. The Hybrid concept of testing to failure could not be applied to facilities and processes. Therefore there is no additional benefit to this skill and the capability is assessed as YELLOW.

The resulting overall rating for the Production Capabilities and Skills area is shown in Table 10. The rating is YELLOW.

Table 10 Hybrid Model - Production Capabilities Assessment

	Equipment/Process Design & Maintenance	Process Control & Assessment	Failure Analysis & Root Cause Determination
ATK	YELLOW	YELLOW	YELLOW
Aerojet	YELLOW	YELLOW	YELLOW

Sustainment Capabilities and Skills

Sustainment efforts would be unaffected under the Hybrid option when compared to the USAF/Navy models. The specific subcategory assessments are identical and the discussion is not repeated here.

Table 11 Hybrid Model - Sustainment Capabilities Assessment

	Systems Engineering & Integration	Aging & Surveillance	Failure Analysis & Root Cause Determination	Nuclear Environmental Issues
ATK	YELLOW	YELLOW	YELLOW	RED
Aerojet	RED	RED	RED	RED

Impact on Competition

While not a perfect solution, the greater focus on pursuit of next generation capabilities provides better opportunity for Aerojet to be competitive in the future. The circumstances improve and this criteria is assessed as GREEN.

Analysis Summary

Table 11 provides a summary of the assessment for the four models. Subcategories for Development and Production skills are rolled up for simplicity.

Table 12 Analysis Summary

	Do Nothing	USAF/Navy	Hybrid
Facilities	YELLOW	YELLOW	YELLOW
Critical Skills	RED	YELLOW	YELLOW
- Development	RED	YELLOW	GREEN
- Production	RED	YELLOW	YELLOW
- Sustainment	RED	RED	RED
Competitive Environment	RED	RED	YELLOW

RECOMMENDATIONS

As Table 12 illustrates, the Hybrid Model marginally improves the situation. Under current policy, America's nuclear strategic deterrent must be credible. As the Task Force on DOD Nuclear Weapons Management concluded, "there has been an unambiguous, dramatic, and unacceptable decline in the Air Force's commitment to perform the nuclear mission and, until very recently, little has been done to reverse it."³⁴ In Phase II of the effort to assess DOD as a whole, the Task Force "detected some of the same forces at work."³⁵ Given these conclusions a marginal improvement is not enough.

This study discusses three recommendations to retain a robust capability. First, the determination of requirements for the next generation of strategic SRMs is a necessity. Second, the value of continued competition and/or a back-up source for this capability must be evaluated against the option of purchasing appropriate facilities and convert them to GOCO. Finally, the proper level of consistent funding to be provided and the correct prioritization of its use must be determined.

Determine Requirements for Next Generation SRMs

DOD must establish at least preliminary requirements for the next generation of strategic SRMs. This must include system technical requirements, estimates of the quantities necessary, and also the timing of the procurement(s). This will allow whatever resources are available to be better planned and focused in the right direction to ensure taxpayer resources are used in the most effective manner practical considering the inherent unpredictability of the future.

Determine the True Value of Competition, Consider GOCO

For the vast majority of products and capabilities purchased by the government, maximizing competition is unquestionably in the best interests of the taxpayer. Strategic SRM designs are driven by a unique set of performance requirements. The core competencies necessary to design and produce these vehicles, for the most part, are typical of those throughout the Aerospace industry. However, several of the most critical skills, such as dealing with nuclear safety and surety requirements, are only applicable to a small cadre of personnel. The natural selection of market forces has already reduced the number of competitors from five to two. As there is a very high cost of entry into the business, new competitors are unlikely in the foreseeable future.

The government should undertake a serious, detailed evaluation to determine the cost effectiveness of retaining two viable competitors vice having only one source for SRMs if the businesses remain in the private sector. A major consideration must be the value of a back-up source to eliminate the possibility of a single-point failure in the supply chain. As discussed earlier, SRMs production involves potentially explosive hazards. In fact, the most recent competitor to exit the business did so after its plant was destroyed in such an incident.³⁶

An additional option is purchasing the appropriate facilities and converting them to GOCO situations. The logic behind this option stems primarily from Aerojet and ATKs fiduciary responsibility to maximize shareholder profit. Therefore, they must make any and all decisions regarding the upkeep of, or additional investment in their facilities based on the return on the investment. The impact on the government is the manufacturers are not considering potential future national security needs in their decision calculus. In 2007, the SRM business segments Aerojet and ATK obtained in excess of 80 percent of their revenues from DOD and other government customers.³⁷ This means taxpayer dollars are already providing for the cost of maintaining these facilities so the trade-off must be made only between the price of purchasing the facilities and the cost avoidance of recreating or refurbishing them in the future. Since the government would not have to be concerned with turning a profit, there is the additional option of being able to retain increased capability to surge production should the need arise, albeit at some additional cost. One other complication could arise if, as would make sense, the facilities continued to produce SRMs for space launch. Since this option would clearly subsidize the production, the recent World Trade Organization decisions regarding subsidies on aircraft need to be considered.

Determine and Provide Appropriate, Required, and Stable Funding

This will allow Aerojet and ATK to make more informed business case decisions. As the DSB recommended “The Secretaries of the Navy and the Air Force after planning, programming, and implementing the advanced development programs shall fully fund the Navy and the Air Force Applications Programs at the levels originally recommended by the USSTRATCOM SAG” which, for PAP, was \$40M/yr.³⁸ This funding level has not consistently

been provided as mentioned previously (Figure 3) and over the most recent period has been directed at Conventional Strike Missile demonstration motors.

The necessary funding must be provided for the design/development and low-rate production efforts. It is critical the new funding NOT be diverted from MM III or D-5 sustainment programs. The warm-line production funds must be used to maximum impact on the industrial base while protecting the viability of the deployed systems. As discussed in the analysis, the USAF has previously not used a low rate continuous production approach. They emphasized demonstration/validation to maintain necessary technical skills in the industrial base. This resulted in dependence on “the stability of other programs, such as the Trident D-5” to maintain the infrastructure.³⁹ Meanwhile, the Navy has used a low rate production program to gradually replace their oldest SRMs with newer ones of the same configuration and has placed less emphasis on Aging Surveillance and demonstration/validation efforts to minimize the programmatic risk of sustainment through 2042.⁴⁰ The Air Force is currently developing plans for a warm-line like program, but because the MM III designs currently deployed use 1970s technology, it should not follow the pattern of the Trident efforts. The USAF version should incorporate technologies demonstrated on the PAP program and use motors produced for flight demonstration and qualification of what should become the next generation of Minuteman. Research and Development along with Demonstration/Validation funds must also be used in the most effective way possible. The operating concepts and environments for MM III and D-5 (along with any successor system(s)) are significantly different. Therefore a completely joint effort for research and demonstration/validation type projects would not be effective. Still, there are many similarities. Motor case structural and insulating materials, nozzle component

materials, and flight control systems could and should continue to be closely coordinated. This approach minimizes duplication of efforts and maximizes value to the taxpayer.

In addition to more traditional development project, this research recommends the inclusion of efforts specifically geared toward performing failure analysis and the determination of their root causes. This becomes more likely to be a necessary skill as the motors continue to age. It is also the best way to reach the necessary depth of understand the design and function of an SRM so the next generation is created successfully. This recommendation could be accomplished by using excess assets from any of the previous strategic systems SRMs (MM II, Polaris A3, or Trident I C-4) as test subjects. In order to develop the necessary skills, one team could design a flaw and predict a failure mode, a manufacturing team would create a process to induce the flaw, and a third team would perform the post-test failure analysis. This could provide an additional benefit. A program of this nature would have an excitement factor enabling the attraction of new talent into this business area.

CONCLUSION

Many factors, from general economic conditions to technology improvements, have conspired to reduce demand for high performance SRMs. What has not changed is the US commitment to allies to provide the deterrent capability of the nuclear umbrella. This has placed the two remaining manufacturers in a precarious position. The potential business opportunities may not provide sufficient return for their shareholders, forcing them to consider exiting the industry.

SRMs for space launch applications, for either commercial or government customers, could be replaced (albeit at greater cost) with options such as LRMs. DOD, however, is

absolutely dependent on this capability for the ICBM and SLBM strategic deterrent forces. Current capability is sufficient and deteriorating slowly enough to sustain deployed systems in the near to medium term. The strategic SRMs are may require replacement sometime in the 2020s. The DSB has concluded the critical capabilities and skills required to design, test, and produce these SRMs is at high risk of being unavailable later this decade – when the replacement process would start. The current low rate production efforts underway (Navy) and being planned (USAF), along with the research and development (IPHRPT, TSSS) and demonstration/validation (PAP) projects are a step in the right direction. All the efforts require more robust funding, at a minimum in line with prior DSB recommendations, to assure the capability for the next generation SRMs. This funding needs to start now and continue at least until the replacement programs commence to avoid the delays and additional costs incurred if a cold restart of these operations were necessary. Along with the increased funding, the industrial base sustainment efforts should also be concerned with developing a key capability not currently utilized – the ability to assess and determine the root cause of a failure in the system.

Finally the government must take a hard look at the cost of ensuring both Aerojet and ATK are financially sound and possess the critical skills and abilities necessary to produce future SRMs. This should be carefully weighed against the benefits of competition for future systems and precluding single-point failures in the system. If competition is not deemed worth the investment, the government should seriously evaluate the option of acquiring facilities with appropriate capacity from Aerojet and/or ATK and initiating a GOCO process to run those facilities.

The 2010 Nuclear Posture Review Report stated “as long as nuclear weapons exist, the United States will maintain a safe, secure, and effective arsenal, both to deter potential

adversaries and to assure U.S. allies and other security partners that they can count on America's security commitments."⁴¹ SRMs are a critical piece of that arsenal. If the US does not take the necessary steps to retain the capability now, who will build them?

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³ Department of Defense, Report of the Defense Science Board Task Force on Future Strategic Strike Skills, Washington, DC, March 2006, 24

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⁵ Lethbridge, Cliff, History of Rocketry Chapter 6 – 1945 to the Creation of NASA, <http://www.spaceline.org/history/6.html>

⁶ National Park Service, "History of Minuteman Missile Sites", <http://www.nps.gov/archive/mimi/history/srs/history.htm>

⁷ Briefing, OUSD(Acquisition, Technology & Logistics)/Industrial Policy, Subject: Solid Rocket Motor (SRM) Congressional Interest, December, 2009, 5

⁸ Briefing, OUSD(Acquisition, Technology & Logistics)/Industrial Policy, Subject: Solid Rocket Motor (SRM) Congressional Interest, December, 2009, 48

⁹ The Office of Under Secretary of Defense, Acquisition, Technology & Logistics, Industrial Policy, *SRM Industrial Capabilities Report to Congress – Redacted Version*, Washington, DC, June 2009, 10

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¹³ Briefing, Air Force Global Strike Command/A5C, Subject: Solid Rocket Motors

¹⁴ Holdren, John P, Director, National Aeronautics and Space Administration (NASA) Office of Science and Technology Policy (OSTP), To Honorable John D. Rockefeller, Honorable Kay Bailey Hutchinson, Honorable Bart Gordon, Honorable Ralph Hall, 22 December 2009

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¹⁷ Caceres, Marco; "Declining trend for US launch capabilities"; *Aerospace America*; Volume II, March 2006, 16

¹⁸ The Office of Under Secretary of Defense, Acquisition, Technology & Logistics, Industrial Policy, *SRM Industrial Capabilities Report to Congress – Redacted Version*, Washington, DC, June 2009, 9

¹⁹ The Office of Under Secretary of Defense, Acquisition, Technology & Logistics, Industrial Policy, *SRM Industrial Capabilities Report to Congress – Redacted Version*, Washington, DC, June 2009, 13

²⁰ Butler, Amy; "DOD Studying Rocket Motor Sustainment"; Aviation Week & Space Technology; <http://www.aviationweek.com/aw/generic/story.jsp?id=news/asd/2010/02/08/11.xml&channel=defense>, February 8, 2010

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²³ Department of Defense, Report of the Defense Science Board Task Force on Future Strategic Strike Skills, Washington, DC, March 2006, 24

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- ²⁶ Department of Defense, Report of the Defense Science Board Task Force on Future Strategic Strike Skills, Washington, DC, March 2006, 26
- ²⁷ The Office of Under Secretary of Defense, Acquisition, Technology & Logistics, Industrial Policy, *SRM Industrial Capabilities Report to Congress – Redacted Version*, Washington, DC, June 2009, 43
- ²⁸ Department of Defense Instruction (DOD-I), Operation of the Defense Acquisition System, December 8, 2008
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